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PATENT & TRADEMARK OFFICE
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Board of Patent Appeals and Interferences
USPTO
P.O. Box 1450
Alexandria, VA 22313-1450
USA

Application No: 10/774,948
Appeal No: 2011-012771

November 24, 2011

Dear Sirs,

As one of the named inventors behind this patent application, the undersigned hereby would like to draw your attention to some important facts relating to the application. The US patent application 10/774,948 claims priority from the Swedish patent application 0103279-6, which basically describes a new image compression method especially suited for laser based measuring systems. The inventors were me and a colleague, Anders Åström, both of us working for the Swedish company Soliton Elektronik AB. The Swedish application was obtained by the present applicant, SICK/IVP AB, when Soliton went bankrupt in 2002. SICK/IVP AB then proceeded with patent applications to USPTO and EPO without the involvement of the original inventors.

The US application, being based on the PCT application written by the new applicant SICK/IVP AB one year after the Swedish application, contained both additions to the description as well as a new set of claims. The new claims were quite different from the claims in original application. As inventor, my opinion is that the scope of the claims in the revised application extends far beyond the contribution from the actual invention. Consequently, I as well as the other inventor refused to sign the Information Disclosure Statement attached to the US patent application. The inventors' declaration was instead signed "on behalf of the inventors" by Mr. Mats Gökstorp, the former CEO of SICK/IVP AB, despite the fact that I had informed their lawyer at that time of the existence of an installation of a system that would fall within the scope of the new claims. This system had been described in a public Master's degree thesis, published in December 2000, i.e. 9 months before the priority date. This thesis was not included in the original IDS filed before the oath signed by Mr. Mats Gökstorp on July 20, 2004, despite the information I gave them when refusing to sign the declaration.

The thesis was written in Swedish by Mr. Mattias Forslund and had the translated English title "EVALUATION OF NEW TECHNIQUE AT DIMENSION MEASUREMENT OF SAW TIMBER". Included in the thesis is also as an attachment a CD containing measurement results from the described system. The applicant did indeed file a new IDS three years later on August 1, 2007, where this thesis was mentioned, but apparently only a few pages were included and translated and no reference was made to the CD which was a published part of the thesis.

However, despite the quite extensive examination by the USPTO, no reference was made to this highly relevant material. It's understandable that the examiner didn't take full notice of the

significance of this non-patent literature written in Swedish. The importance of this document is emphasized by the fact that EPO in December 2010 decided, after opposition, to revoke the corresponding European patent EP1432961 in its entirety, their decision being solely based on this thesis. Actually, EPO found that the written thesis alone without reference to the CD was sufficient to revoke the patent. This patent had been granted 2006 without consideration of this thesis.

Without commenting on the arguments from the parties during the USPTO examination, the undersigned inventor is of the opinion that this thesis is a more obvious prior art than the patents referred to by the examiner and therefore would like to draw the Board of Appeal's attention to the existence of this document. A partial translation into English of this document is attached, the most relevant pages being 9-11. This translation was during the opposition proceedings at EPO accepted by the applicant SICK/IVP AB as being a correct translation into Swedish. A complete copy of the Swedish original (58 pages) can be submitted upon request. Also included is a copy of the CD and an analysis of the CD made by the undersigned inventor and presented to the EPO during the opposition proceedings. If there are any questions regarding this material, contact details are given below.

Yours sincerely

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REPORT

Mattias Forslund

Evaluation of new technique at dimension measurement of saw timber

Translation from Swedish into English of title page, table of contents, pages 1-3, 9-12, 19 and appendix 4. Also includes the original English abstract.

Mattias Forslund

EVALUATION OF NEW TECHNIQUE AT DIMENSION MEASUREMENT OF SAW TIMBER

Trätek report P 0012041

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Master Thesis No 48/00
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Keywords

bark
dimensional measurement
lasers
saw logs

Stockholm December 2000

ABSTRACT

Damaged bark is a large source of errors in today's dimension measurement of unbarked saw logs. This work describes an evaluation of a prototype that detects bark on one side of logs. The bark-detecting machine operates with laser- and camera technology and detects the bark using the tracheid effect.

Five methods to evaluate the bark-detecting machine have been tested, each one has its good and bad sides. The selection of a method should because of this be based on the purpose of the investigation.

The evaluation of the bark-detecting machine shows that the result is correct for 84 and 91 percent of the area respectively depending on which method is used. The accuracy depends of how frequently and in which proportions the cases that are hard to detect appears. To get the bark-detecting machine to work as good as possible the logs ought to be clean and have a short storage time. When bark-detecting machine is going to see around the whole log four cameras should be used. One camera can approximately see somewhere between $^1/_3$ and $^1/_4$ of the circumference of a log.

The detection of different surfaces with the bark detecting machine:

Type of surface	Detection with the bark detecting machine
Clean wood.	Wood
Outer bark.	Bark. Thin lose pieces of the outer bark (top log) and thin edges on bark (root log) can be detected as wood/grey zone.
Inner bark.	The detection of inner bark is depending of how long time the inner bark has been exposed to the surrounding air. Visually white inner bark will be detected as wood and visually brown inner bark will be detected as bark.
Knot.	Most of the knots are detected as bark but in the detail study knots where detected as wood. The knots in the detail study had a fine cross cut and where visually white and clean.
Mould/blue stain on wood surface.	Substantial attacks will be detected as bark or grey zone but small attacks will be detected as wood.
Wood storage with water sprayed on the logs.	The logs has been sprayed with water, the detection will go from wood to bark as a function of the time.
Thin brown covering on wood surface. (Very thin dried inner bark)	Can cause that wood will be detected as bark.
Wet surface	The tracheid effect will increase. The number of pixels that are detected as wood and grey zone will increase, the largest increase happens on surfaces of inner bark.
Ice	Ice is tending to increase the effect that some edges of bark and lose thin outer bark is detected as wood. The type and the surface of ice can probably effect the result and should be investigated further.
Snow	Should be controlled under real circumstances.
Mud/gravel/bark pieces on wood surface	The areas with pollution will be detected as bark/grey zone.

Keywords: Bark, damaged bark, bark-detecting machine, dimension measurement, laser, saw logs, tracheid effect.

TABLE OF CONTENTS

APPENDICES

1. Pixel method procedure
2. Grayscale method procedure
3. Seeing differences between images using Scion Image
4. Contents on Cd-disc[1]

1. If appendix 4 (Cd-disc) is not attached to the inside of the cover page it can be borrowed from Trätek's library, Tel 08-76211828.

1. INTRODUCTION

1.1 Background

The Council for Measurement of Timber (Virkesmätningsrådet, VMR) started in April 1, 1999 the project Improved Measurement of Saw Timber consisting of the following three sub projects:

- Method development
- Technology development
- Measuring site development

The sub project technology development was conducted at AB Trätek (the Institute for Wood Technology Research) with Hans Dutina as project leader.
The project refers to development of technology for automatic determination of:

1. Bark presence and log dimension under bark.
2. Wood species.
3. Detection of harvesting cracks.

For more information on the project Improved Measurement of Saw Timber see www.virkesmatningsradet.org .

1.2 Purpose

To evaluate the measurement technology for detection of bark presence (the bark presence measuring device) regarding detection of bark, wood, bark boundaries and damages.

1.3 Objectives

To develop an evaluation routine including tools to compare the results from the bark measuring device with a manual measurement regarding bark presence.
To evaluate the bark presence measuring device

2. THEORY

2.1 Saw timber measurement

2.1.1 General about saw timber measurement

The dimension of saw timber is first measured in the forest for optimal placement of the cut and then often twice in the saw. The first measurement in the sawmill is done to determine payment and sorting dimension and the second before the breakdown as verification and in certain cases to support saw blade positioning.[1]

The measurement serving as a basis for calculation of payment and dimension sorting is often done on non-barked logs[2]. Dimension is measured on the bark and a timber measurer is judging wood species, quality, bark type and bark presence. By automating the manual judgments which are both labor intensive and difficult, the capacity and accuracy on an individual log level can be increased.[3]

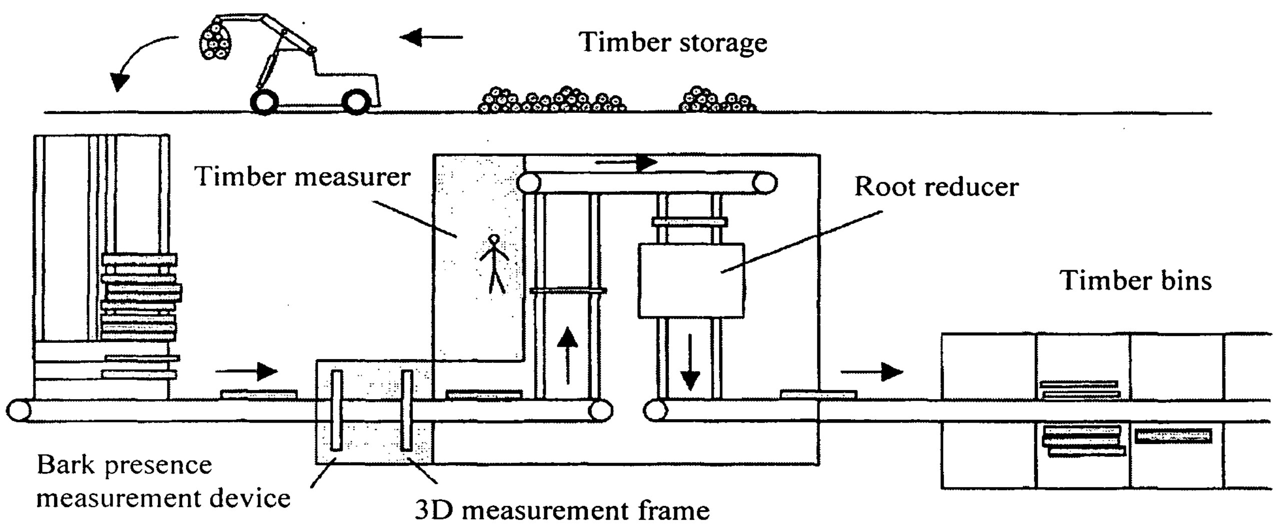

Figure 2.1 Saw timber measurement and timber sorting at AB Forssjö Bruk

2.1.2 Why is the bark a problem?

At dimension measurement and sorting on an individual log level there are three dominating error sources: the non-circularity of the log, presence of bark and bark thickness.[4] When using a one- or two-direction shadow measuring frame, the influence of patches of missing bark can be judged manually. Using a 3D measuring system, considerably more measuring points per cross section are obtained and the influence of missing bark on the measurement result is more difficult to estimate.[5] Knowledge about presence of bark will increase the accuracy when determining the dimension of saw timber containing patches of missing bark. Logs with the bark intact or completely free of bark will not be affected. For the logs having patches of missing bark, the precision will be mostly increased for the logs having the thickest bark. However, the division into classes will cause certain logs to be critical and others not, and depending on the sorting function certain areas of the log can be more critical than others.

1. Right log to right class, 1992. **2.** Grönlund part 1 & 2, 1992. Diameter sorting of saw timber, 1986.
3. www.virkesmatningsradet.org (improved saw timber measurement). **4.** Grundberg et.al., 1998. Conversation with Hans Dutina Trätek. **5.** www.tratek.se (tests with improved bark reduction at diameter measurement on spruce, 2000)

2.1.3 Why measuring on and not under the bark?
If the saw timber is debarked before the dimension measurement the problem with missing bark and bark thickness will disappear.

Reasons for this solution are the following[1]
1. Higher accuracy at dimension measurement and sorting.
2. No debarking machine in the saw line.
3. No errors due to bark functions and judgment of bark type.
4. Attacks from micro organisms are reduced.

Drawbacks by measuring on debarked timber[1]
1. The bark is a protection against damag when handling the logs.
2. Storage of debarked logs requires a larger storage area.
3. The logs will become more slippery which will make the handling more difficult and increase the risk of accidents.
4. The sound level when the logs fall into the sorting bins increase.
5. Dust and gravel will follow the logs into the saw line.
6. Remaining cambium layer will favor the growth of mould/blue stain.

LogScanner – direct measurement of dimension under bark on non-debarked saw timber
By using x-ray the dimension under bark is measured in two directions, measurement can be done directly on non-debarked logs. This method also gives information about log type, knot positions, density etc. The advantage with all information is that individual logs can be sorted before breakdown into the most suitable product. Bark is not a problem for dimension measurement and sorting but can remain on the log for protection. Due to the dimension being based on two measured diameters there is the problem with non-circularity.[2]

2.1.4 How to measure bark presence and bark thickness
To be able to automatically measure bark presence and bark thickness there must be measurable differences in the material. The differences between bark and wood are, among other things, the following[3]
- Color
- Density
- Chemical structure
- Anatomical structure
- Strength
- Acoustic properties

Technologies that could be used are for instance camera technology (color), camera technology in combination with the Tracheid effect, ultrasound (echo registration), laser triangulation, gamma- or x-ray radiation[4].

Esping, 1996 & 1998. Grundberg et al., 1998. Conversation with Jonas Olsson SCA & Johan Oja Trätek/Luleå Technical University. 2. Grundberg et al., 1988. Oja 1999. 3. Saarman, 1992. 4. Seltman, report 41,42 & 43. Åstrand, 1996. www.soliton.se. www.ivab.se. www.catech.se.

2.3 Bark presence technology

2.3.1 Prototype installation

The bark presence measurement device is a single-sided prototype equipment for detection of bark presence on the logs at the dimension measuring, see picture 2.1 and figure 2.1 (page 2). The equipment is mounted at the saw mill AB Forssjö Bruk in Forssjö.

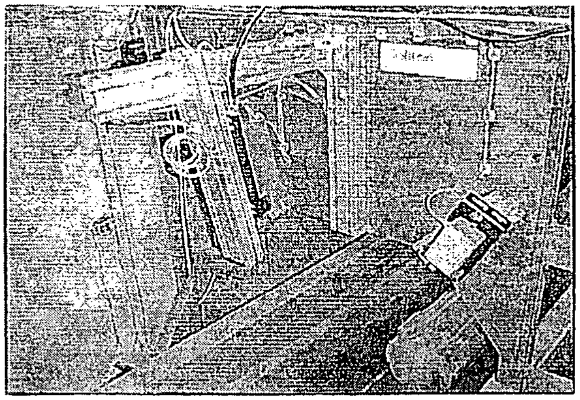

Image 2.1 Single-sided bark presence measurement device

The single-sided bark presence measurement device comprises a multi sensor camera[1] and two line lasers and uses the Tracheid effect[2]. With the multi sensor camera the frame recording can be made with high capacity simultaneously as several measurements can be made simultaneously, location according to fig 2.8 and 2.9 numeral 1. The power of the line lasers are 30 mW with a wave length of 670 nm (visible red laser), see numeral 2 in figures 2.8 and 2.9. Lasers and camera are mounted in different planes in order to use laser triangulation[2] to see differences in height. Triangulation takes place along the entire laser line.

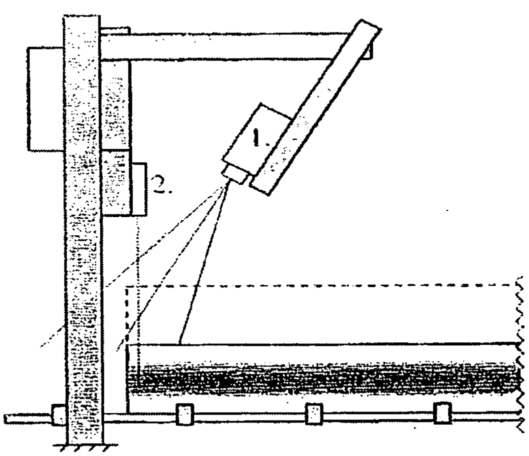

Figure 2.8 Single-sided bark presence measurement device

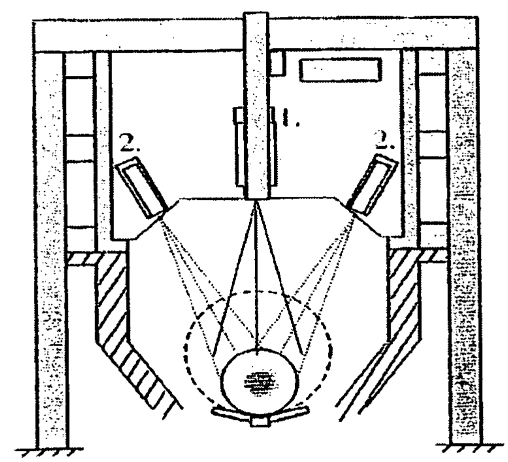

Figure 2.9 Single-sided bark presence measurement device

The line lasers place a laser line across the length direction of the log and the laser light receive different propagation in the longitudinal direction depending on the type of surface. The wood fibers (tracheids) of the wood propagate laser light well in the direction of the fibers, the bark that has a different structure does not propagate laser light. Coatings obstructing the tracheids and fiber disturbances as for instance knots thus influence the light propagation. The camera registers at certain intervals (measuring frequency) the light propagation and based on this the computer can reconstruct the surface for each measuring occasion. The images that are generated by the bark presence measurement device are built up of rows of pixels where the dimension of the pixel lengthwise depends on the speed of the chain conveyor and the measuring frequency. Se figure 2.11 for more

1. Åstrand, 1996 www.soltion.se. **2.** Seltman report 42 & 43, 1998, 1989. Åstrand, 1996

information on pixels. Crosswise the dimension of the pixels depends on the distance between camera and log surfaces and will therefore vary depending on log dimension. The measuring frequency for this equipment is 400 Hz (times/s) and the speed of the log conveyor is 1 m/s.

The equipment can for testing purposes create three different types of images, gray scale image, tracheid image and bark image. In addition to the images height data that describe the dimension of the pixels laterally can be obtained from each measurement. The apparatus will in its final shape only deliver the bark picture as a base to determine the presence of bark.

Laboratory equipment
At the laboratory test only one line laser was used and the test sample was conveyed by hand through the measuring equipment. The line laser was placed vertically above the test sample. Adjustment of apparatus and program was chosen so as to resemble that of the prototype equipment as far as possible. Figure 2.10 shows the equipment that was used.

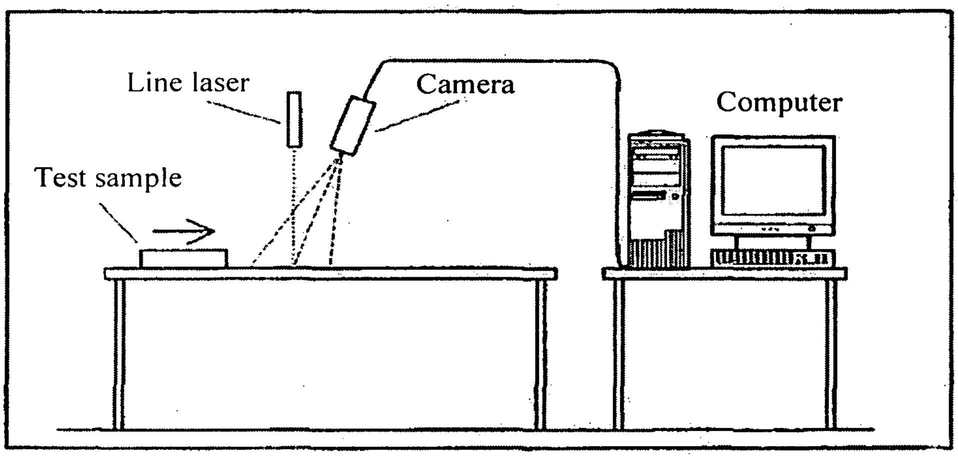

Figure 2.10 Laboratory equipment

Resolution and pixels
Figure 2.11 consists of 120 pixels (8*15). The resolution is 3 pixels per cm lengthwise and 4 pixels per cm laterally. The resolution is thus greater laterally than longitudinally. The pixels that are the smallest units in a picture may have different pixel depths (point resolution). The pixel depth is a measure of the number of data bits of information that is stored in each pixel, for instance pixel with a bit depths of 8 has 2^8, that is 256 possible color values (levels).

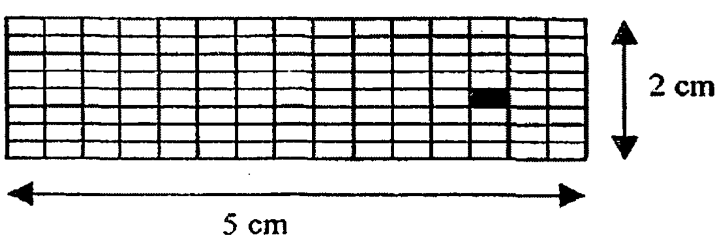

Fig 2.11 Image of an area that in reality has the dimension 2*5 cm.

2.3.2 Output data from the bark presence detection device

As an aid at the evaluation of the single sided bark presence detection device the system has generated gray scale images. Bark image and gray scale image are made in different ways but are as images very similarly built. The images have the same size about (100 kb/m log), the coordinate systems are alike and one pixel in the length direction corresponds to approximately 2,5 mm/pixel (4 pixels per centimeter).

Gray scale image

Gray scale images according to image 2.2 are created by the camera registering reflecting light from the center of the laser line. The picture is constituted by 256 levels of gray scale from black to white. The coordinate system starts from the upper left corner. Laterally the picture has 256 pixels. The number of pixels lengthwise depends on log length.

Image 2.2 Gray scale image from bark presence measurement device

Bark image

Bark images according to image 2.3 are filtered tracheid images and consist of three different colors. Black = bark, white = wood and grey = grey zone. The coordinate system starts from the upper left corner, laterally the picture has 256 pixels. The number of pixels lengthwise depends on log length.

Image 2.3 Bark image from bark presence measurement device

Height data

By using, during the same measuring, so called smart image sensor technique more information can be collected.

Height data provide information of the lateral dimension with three decimals for an individual pixel. This can be used to determine lateral distance and in the future compute the bark thickness. The lateral dimension of the pixel is dependent on the height over the log chain conveyor, that is the pixel in the highest point is different for different dimensions of logs. A larger log give a lesser lateral dimension of pixel, an estimation of the relation can be found in table 2.6. One mm heightwise corresponds to about 0,02 mm difference of lateral dimension in height data. The size of a height data file is about 815 kb/m log.

Table 2.6 Relation between log dimension and pixel dimension (own estimate)

Dimension of the pixel laterally	Log dimension
1.6 mm	340 mm
1.9 mm	190 mm

2.4 Measuring frame technology

2.4.1 History

From manual measurement of dimension of saw timber, machine installations for dimension measurement begun to appear on the market in connection with timber measurement being performed in the industry. Length measurement is usually done by means of photo diodes and a pulse encoder registering the movement of the chain conveyor and thereby the length of the log.[1] Dimension measuring can be done using

- IR-light
- Laser
- Ionized radiation (gamma- or x-ray radiation)
- Camera technology

Table 2.7 shows how many measuring points some different types of dimension measurement devices are using to determine the dimension of the saw timber. A major difference between the different types is that the LogScanner can measure under bark, the others are measuring on bark.

Table 2.7 Number of measuring points for different diameter measuring devices (own compilation).

Type of device	Number of measurement points	Number of diameters
1-direction optical	2	1 (circle approximation)
2-direction optical	4	2 (elliptical approximation)
2-direction optical	6	3
3D measurement system	36 (calculated from max 48 points)	18
LogScanner	4	2 (elliptical approximation)

2.4.2 RemaLog 3D[2]

RemaLog 3D (figure 2.13) is a measuring frame with three measuring units. Each measuring unit consists of 16 lasers with invisible infrared light (780 nm). Measurement points on the log surface are obtained using laser triangulation. A maximum of 48 measurement points per cross section can thus be obtained if all lasers hit the log. The measuring frequency is 250 Hz which means that a chain conveyor speed of 1 m/s gives 4 mm per measurement point lengthwise. In order to always get the same number of measurement points for each cross section, 36 points are calculated, that is one for each 10 degree according to figure 2.12.

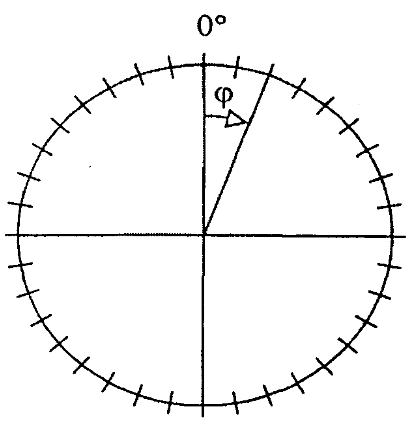

Figure 2.12 Calculated measurement points each 10 degree. Feeding direction into figure.

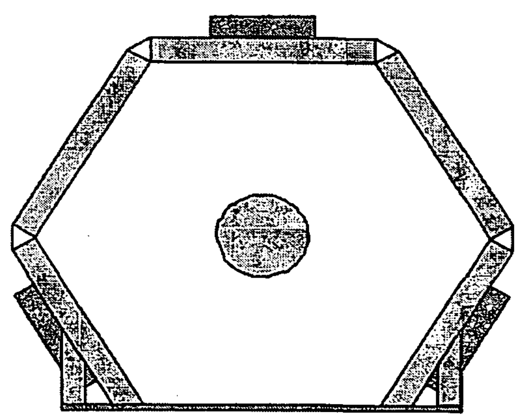

Figure 2.13 RemaLog 3D manufactured by Rema Control AB.

There are four different sorting possibilities: saw pattern selection, block diagonal, average diameter and minimum diameter. Depending on the bark type given by the timber measurer, the bark reduction value is sent to the 3D measuring frame from the supervising system. The bark presence measurement device will transfer information about bark, wood or don't know (gray zone) to the 3D measuring frame for each one of the 36 points per cross section.

1. Asplund, 1982. Grundberg et al., 1988. Grönlund part 1, 1992. www.virkesmatningsradet.org. 2. Rema Lod 3D user manual, 2000. Rema Log 3D File format log data files, 2000. www.rema.se.

4. MATERIAL

4.1 Verification test 1

To verify how the park presence measurement device detects wood, bark, bark boundaries and special cases a verification test was performed in week 26. The limited area that was verified regarding bark presence was carefully selected, see figure 4.1. The selection of area was done so that both wood, bark and boundary between them were present or there has been some other interesting coating on the wood surface. The selection of the log itself was on the other hand done randomly. Manual measurement has been performed in 50 cm on one side along an assigned x-axis. Crosswise, 1/6 of the circumference has been measured, two of the logs have two measurement areas. Diameter and length are measured by measuring tape, bark thickness is measured by calipers.

Table 4.1 Material at verification test 1

Log no.		**1a**	**1b**	**2**	**3a**	**3b**
Wood species		Spruce	Spruce	Spruce	Pine	Pine
Bark thickness [mm]		6	6	5	10-19[1]	10-19[1]
Diameter Measuring end, D_{start} [mm]		190	190	290	260	260
Diameter Butt end, D_{end} [mm]		220	220	225	225	225
Total length of the log		-	-	-	-	-
Measuring area length, A [cm]		50	50	50	50	10
Misc.	Log 1a	Dry + rain				
	Log 1b	Mould + gravel				
	Log 2	Brown, 3 weeks storage				
	Log 3a	Fine wood. Both new & old cambium				
	Log 3b	Fine cambium				

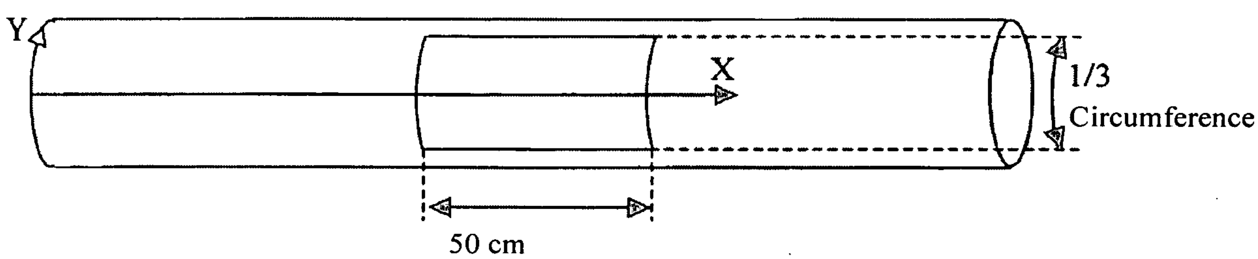

Figure 4.1 An interesting area on the log is selected

Appendix 4 contains grayscale-, bark- and Tracheid-images, height data and digital camera images.

1. The log's bark thickness variation.

Appendix 4 Contents of Cd-disc[1]

Parameter test w020, Forssjö Bruk
- Material
  - Tracheid images
  - Grayscale images
  - Digital camera images
- Results
  - Progress report parameter test w020
  - Appendix 1,2 & 3

Verification test w026, Forssjö Bruk
- Material
  - Tracheid images
  - Grayscale images
  - Bark images
  - Digital camera images
  - Heigth data
- Results
  - Progress report verification test w026
  - Appendix 1,2

Verification test w031, Forssjö Bruk
- Material
  - Tracheid images
  - Grayscale images
  - Bark images
  - Digital camera images
  - Heigth data
- Results
  - Progress report verification test w031
  - Appendix 1-6

Detail study w036, lab
- Material
  - Tracheid images
  - Grayscale images
  - Bark images
  - Digital camera images
- Results
  - Progress report detail study w036

Detail study - ice w044, lab
- Material
  - Tracheid images
  - Grayscale images
  - Bark images
  - Digital camera images
- Results
  - Progress report detail study – ice w044

Digital camera images of bark, process and equipment
  - 21 different images

Templates
  - Template for digital camera image
  - Template for Excel images
  - Documentation form for manual measurement
  - Documentation form for measurement data from bark presence measurement device images
  - Log facts

1. If appendix 4 (Cd-disc) is not attached to the inside of the cover page it can be borrowed from Trätek's library, Tel 08-76211828.

Analysis of the Forslund appendix 4 CD

The appendix (Swedish *bilaga*) 4 consisting of a CD is a published part of **D5**. The last printed page of the document contains a picture of the CD itself, looking as shown in Figure 1, and a printed table of contents.

Figure 1. The appendix 4 CD.

Structure of the CD

The folder structure of the CD is shown in Figure 2. The different sub-folders correspond to the structure of the printed table of contents, although the folders in the screen copy are reorganized in alphabetic order by Windows.

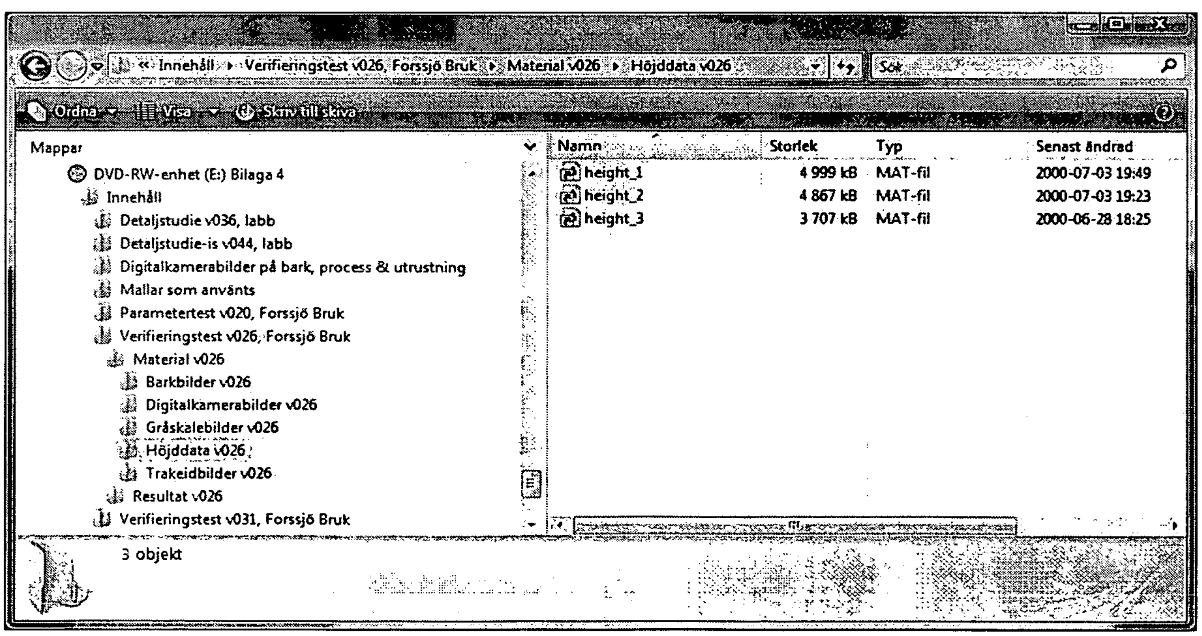

Figure 2. Folder structure of the CD.

The different folders correspond to different experimental tests of the bark detection device as referred to in different sections of the Forslund thesis. For instance, the "Verifieringstest v026, Forssjö Bruk" folder contains the result from the verification test run in week 26 at the sawmill Forssjö Bruk in Sweden. This particular test is presented in section 4.1 at page 19 of the thesis.

Each test folder contains sub-folders with different types of data from the test. Of special interest is the folders *Trakeidbilder* (Tracheid or scatter images) and *Höjddata* (Height data). Each such sub-folder contains, in this particular test, three files corresponding to the three logs in the test so that for instance log 1 generated data as follows:

Trakeidbilder v026\trach_1.bmp	(tracheid, i.e. scatter, data)
Höjddata v026\height_1.mat	(height data)

Other tests contain more logs. The "Verifieringstest v031" for instance contains 10 logs and thereby 10 files in each sub-folder.

Contents of the data files

The tracheid data are stored in a standardized image format called .bmp (bitmap) while the height data are stored as a MATLAB .mat matrix format file. While the .mat file extension by the skilled person is immediately recognized as a MATLAB file, the file may also be opened as a text file, for instance using Windows notepad as shown in figure 3.

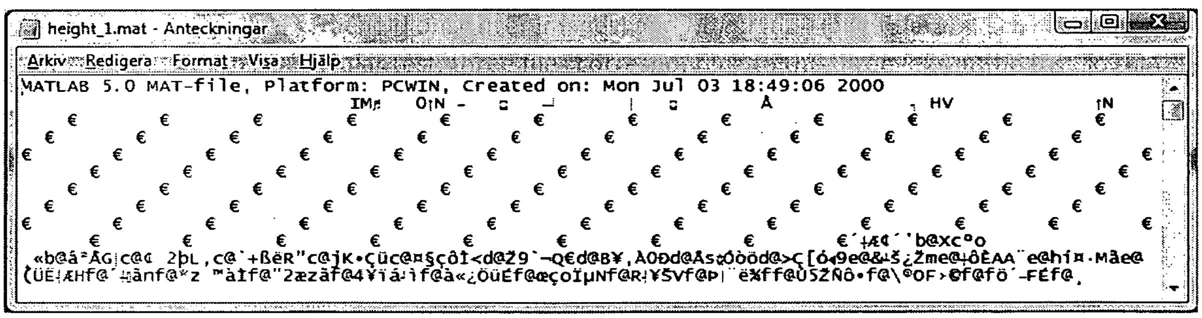

Figure 3. Height data file opened as a text file.

From this it is clear that this is a binary file format with a MATLAB text header in the beginning of the file. The header includes the creation date, which also confirms that the file was created around week 26 2000.

The fact that the MATLAB file format was chosen for the height data, while a standardized image data format was chosen for tracheid data has a natural explanation. The tracheid data are 8-bit integers, which naturally lend themselves to be saved in a compact image data format, while the height data are floating point numbers which are not naturally saved using an image file format. The drawback of the MATLAB file format is the large size of the file. The height data file for log 1 needs nearly 5 Mbyte while the tracheid data from the same log only need 627 kByte.

MATLAB was a tool commonly used in the year 2000 within the image processing and computer vision community to evaluate and process image data. All images are treated as ordered matrices of data of a certain size and the processing is not dependent on the file formats used to read and store the images on the disc. Below is shown the output from a MATLAB session reading the tracheid and

height data for log 1 from the CD. Note that both matrices of data have exactly the same size 256 x 2499 elements.

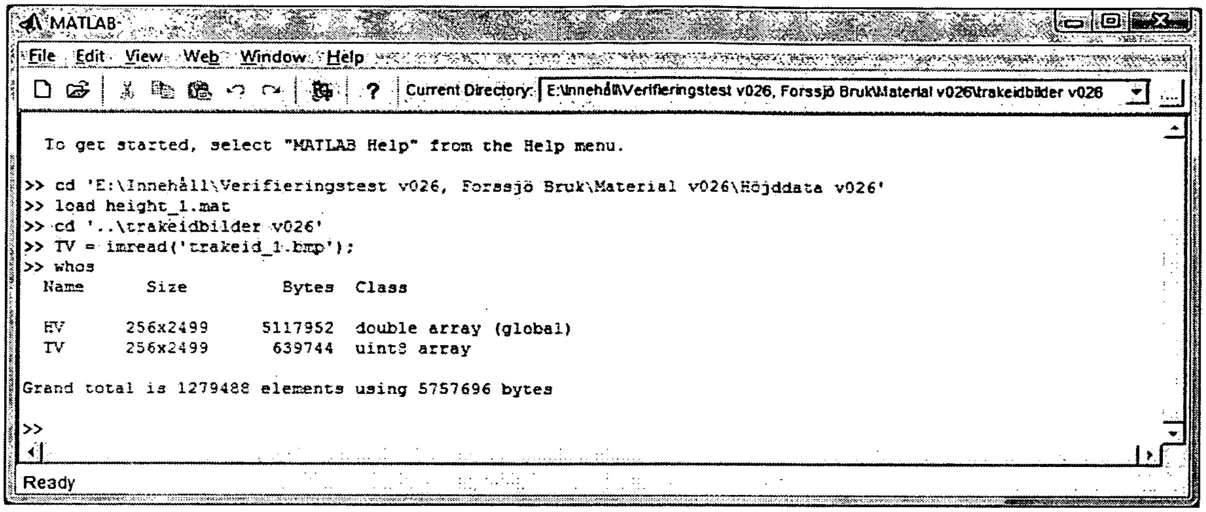

Figure 4. Figure 4. MATLAB session reading the different data files for log 1 of the v026 test.

If this procedure is repeated for other logs it is found that the width of the matrices is always 256 elements while the length varies from log to log. Table 1 below gives the matrix sizes for each log in the two tests "Verifieringstest v026" and "Verifieringstest v031".

	Tracheid data	Height data
Test v026 log 1	256 × 2499	256 × 2499
Test v026 log 2	256 × 2433	256 × 2433
Test v026 log 3	256 × 1853	256 × 1853
Test v031 log 1	256 × 1997	256 × 1997
Test v031 log 2	256 × 1653	256 × 1653
Test v031 log 3	256 × 1639	256 × 1639
Test v031 log 4	256 × 1769	256 × 1769
Test v031 log 5	256 × 2252	256 × 2252
Test v031 log 6	256 × 2135	256 × 2135
Test v031 log 7	256 × 1759	256 × 1759
Test v031 log 8	256 × 1777	256 × 1777
Test v031 log 9	256 × 2018	256 × 2018
Test v031 log 10	256 × 1027	256 × 1027

Table 1. Matrix data sizes for each log.

MATLAB gives the possibility to visualize matrix data as gray level images. If each element is an 8-bit integer, i.e. a number between 0 and 255, the data can be visualized as gray level images where the value 0 corresponds to black and the value 255 to white. The tracheid image for log 1 in the v026 test is shown below.

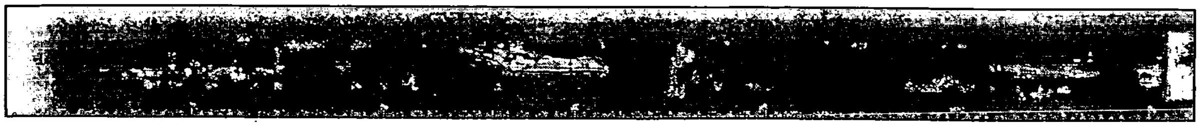

Figure 5. Visualization of tracheid data, log 1 test v026.

In the middle of the log there seems to be a patch of missing bark. As expected the tracheid image shows a high degree of light scattering where the bark is missing and the bare wood is exposed.

According to Forslund (section 2.3.1, page 9), the height data was generated through triangulation along the entire laser line, i.e. using standard sheet-of-light triangulation techniques. The result was a height value for each position along the line representing the distance from the camera or the distance above a reference plane. The common way to visualize such height information was and is using so called *range images* where pixels are given graylevel values representing different height levels, .e.g. where brighter pixels represent a higher level.

To assign proper graylevel values, the first step a person skilled in machine vision would take is to create a histogram plot of the contents of the matrix, as shown in Figure 6, in order to find out the order of magnitude of the data and to establish the interval within which the information is represented. The histogram counts the number of occurrences of each value in the matrix, in this case rounded to the nearest integer since the height data matrix consists of floating point numbers.

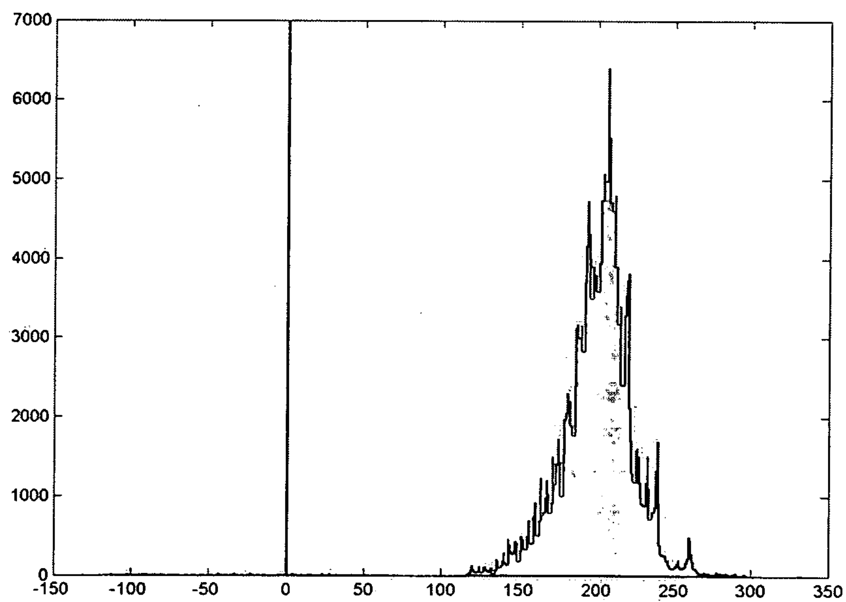

Figure 6. Histogram plot of the height data matrix of log 1 test v026.

The height data matrix contains 256 * 2499 = 639744 elements. The total count of the value 0 is 406649 which far exceeds the vertical scale of the above diagram. The remainder of the data, to which the scale of the histogram plot in Figure 6 is adjusted, are values mainly between 130 and 250. Figure 7 shows a range image of the height data from log 1 using the interval 128-255, i.e. the upper half of the standard 0-255 interval. This means that height level 128 and below are visualized as black, 255 and above as bright and values in between as different graylevels.

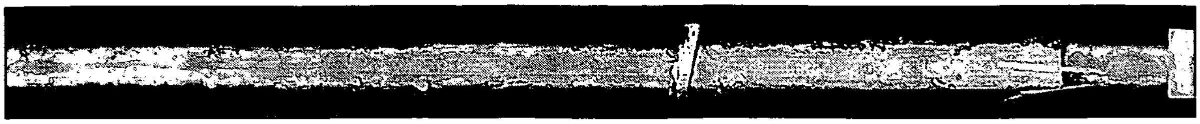

Figure 7. Visualization of height data, log 1 test v026.

This kind of profile image is what a person skilled in machine vision would expect to be the result from a triangulation along the entire laser line as described by Forslund in section 2.3.1 in page 9 of the thesis.

Figure 8 below shows an enlargement in both the profile image and the tracheid image around the patch of missing bark. The graylevels are now further adjusted to visualize the height differences around the patch with missing bark. This image illustrates the high resolution in the height data. The range image is darker within the patch indicating that there is a height difference between the areas within and outside the patch of missing bark. It is this height difference which could be used to measure bark thickness as suggested by Forslund in section 2.3.2 page 11.

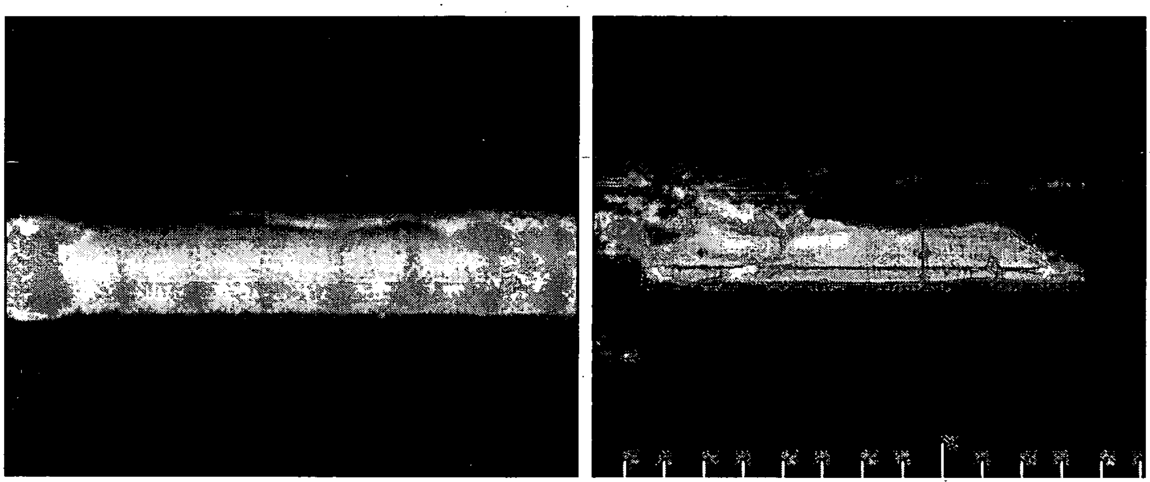

Figure 8. Enlarged profile and tracheid images of the patch with missing bark.

An alternative way to visualize height data is to plot the data as a three-dimensional surface using MATLAB image processing tools. In Figure 9 is shown a so called three-dimensional Mesh-plot of the height data matrix. This illustrates that height data represent information on the three-dimensional shape of the log seen from one direction.

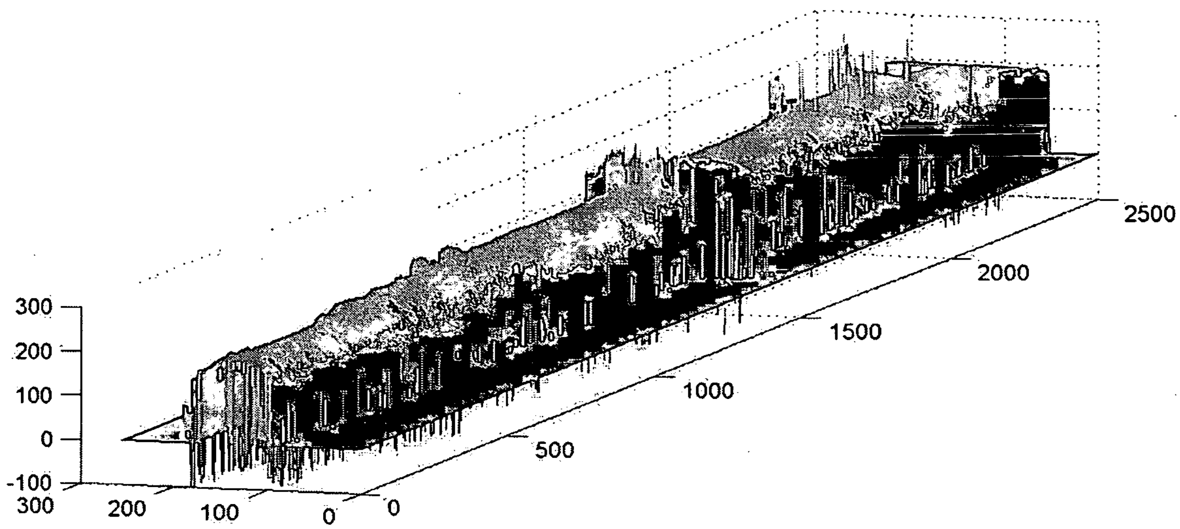

Figure 9. Three-dimensional visualization of the height data matrix.

Matching positions within the different types of data

In both images in Figure 8 there is a horizontal and a vertical line through the patch. The lines originate from pieces of strings attached to the logs as reference lines. This is illustrated by the digital camera image in Figure 10 found on the CD. The digital image is not from the same spot on the log but illustrates how the pieces of string were attached.

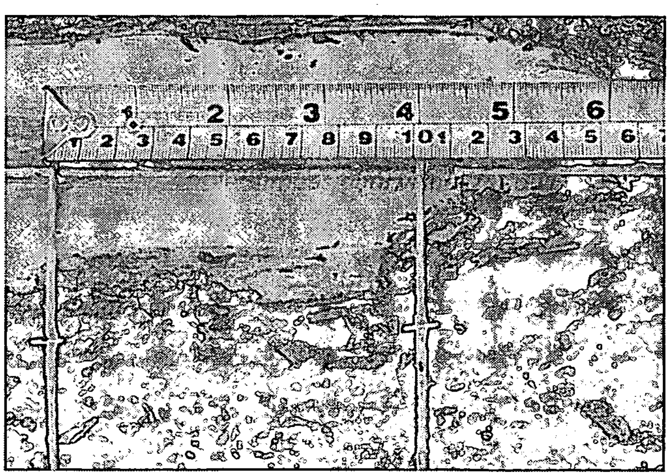

Figure 10. Reference strings attached to the log.

The lines thus seen in the Figure 8 are darker in the tracheid image since the string scatters less light than the wood surface while the lines in the profile image are brighter since they represent a height level above the surface. In Figure 11 the positions where the strings cross each other are enlarged and the pixel positions within the images are also displayed along the axes.

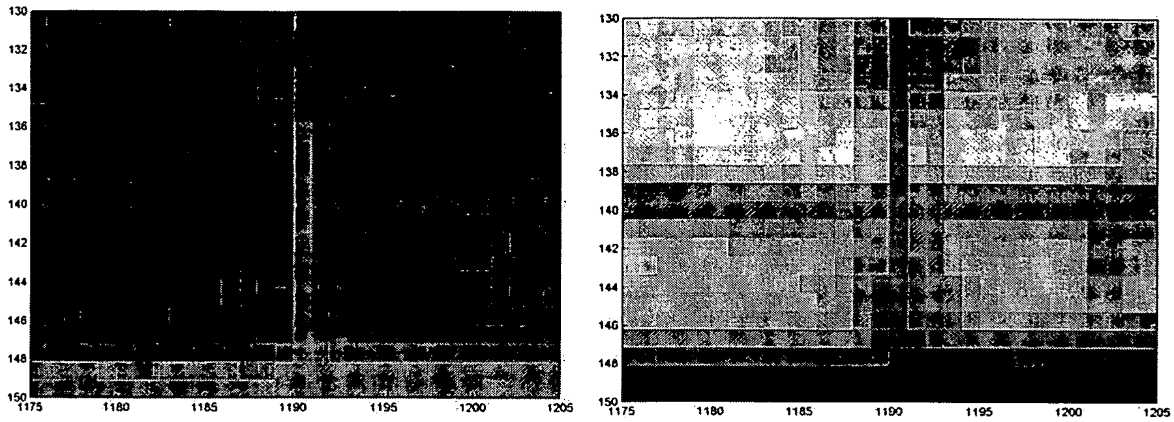

Figure 11. Further enlarged profile and tracheid images of the string crossing positions in the missing bark patch.

Judging from Figure 11, the estimated middle pixel position for the string cross is at pixel (1191,140) in both images. The same correspondence can be found also in other points which can be identified in both images. This is not a coincidence but shows that the height and tracheid data originate from the same measurement and have been simultaneously read out from the same sequence of camera images (i.e. the digital representations) of the single laser line in the system. If the images had not been acquired in this way, there is no way this exact pixelwise correlation could have been achieved. This observation is further supported by the fact that the two images from the same log in all the test runs have exactly the same number of lines.

Färjestaden, February 4, 2010

Erik Åstrand